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Contributed paper

Design of the magnet structure for the Advanced Photon Source superconducting undulator

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A superconducting planar undulator with 9.5 mm pole gap, 16 mm period and required peak field 0.64 T is at present under development at the Advanced Photon Source. Magnet structure precision is a key component of the project. The current design of the magnet structure is based on the assembled jaws with individual poles, while previous designs utilized solid cores with machined coil grooves. Each jaw has a core with pole grooves and separate precise poles inserted in these grooves and fixed with small screws. This approach allows achieving a uniformity of the poles thickness to within 15 μm, improving the surface finish, as well as using magnetic poles with non-magnetic cores. Several 42-pole jaws have already been produced, wound and tested. Magnetic measurements of the first structure have confirmed the mechanical precision of the assemblies. Details of the magnet structure design and jaw assembly, and changes made from the first prototype system to the production unit, are presented here.

1. Introduction

A list of the parameters for the superconducting planar undulator (SCU) is shown in Table 1.

For the prototype (SCU0), we will use a short 42-pole magnet structure that is 330 mm long. Nevertheless, we will build a full-length cryostat capable of accommodating the SCU1 magnet structure. The cross-section of the cryostat with the 42-pole SCU0 magnet structure is shown in figure 1.

2. Magnet structure design

Multiple design choices for the magnet structure were debated. The goal was to achieve the best uniformity of the coil grooves where the superconducting wire is placed during the coil winding. This precision is required in order to achieve the best field quality with only two end correctors. The final decision was to proceed with an assembled version of the core, which is shown in figure 2.

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Electron beam energy	7 GeV
Photon energy at first harmonic	20–25 keV
Undulator period	16 mm
Magnetic length	SCU0: 330 mm SCU1: 1150 mm
Cryostat length	2060 mm
Beam stay-clear dimensions	7 mm vertical, 36 mm horizontal
Magnetic gap	9.5 mm

TABLE 1. A list of the parameters for the Superconducting planar undulator

The core and poles are currently made of 1008 low-carbon steel. All the pole grooves are machined precisely from the same reference plane to secure the tolerance of an undulator period. The pole thickness in such a design is uniform up to 10 μm after grinding and lapping. The surface finish is also extremely good (0.2 μm) due to polishing. The surface of the core was also ground and polished. As a result, after installation of the poles inside the grooves, the area for the coil winding has a very smooth surface, which makes winding process much more reliable from the short-circuit point of view. The precision of the coil grooves is within 25 μm. The bottom of these coil grooves are ground to a flatness of better than 20 μm. After the installation of all poles inside the pole grooves and fixing with #0–60 screws from both sides, we wanted to bring the uniformity of the pole heights to within ±10 μm.

One very important detail is that we made flexturing slots close to the pole face on each pole. Without these slots when the fixing screws were tightening, the pole face deformed slightly. These slots created deformation relief and kept the pole face flat. The assembled core is shown in figure 3, and one can clearly see the liquid helium supply line, an end pole, regular poles and two poles with an extended flat area, which serves to join top and bottom cores after winding and impregnation. Each core has three through holes for a liquid helium supply and a connector, welded on each end, where these holes are joined together. All assembly components were carefully deburred to maintain electrical isolation of the superconducting wire.

There are three sets of two connecting poles, one at each end and another in the middle, on each half of the core. The assembled SCU0 magnet structure is shown in

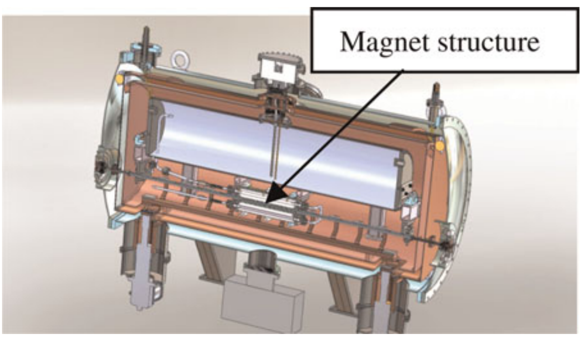

FIGURE 1. Cross-section of the cryostat with the short magnet structure.

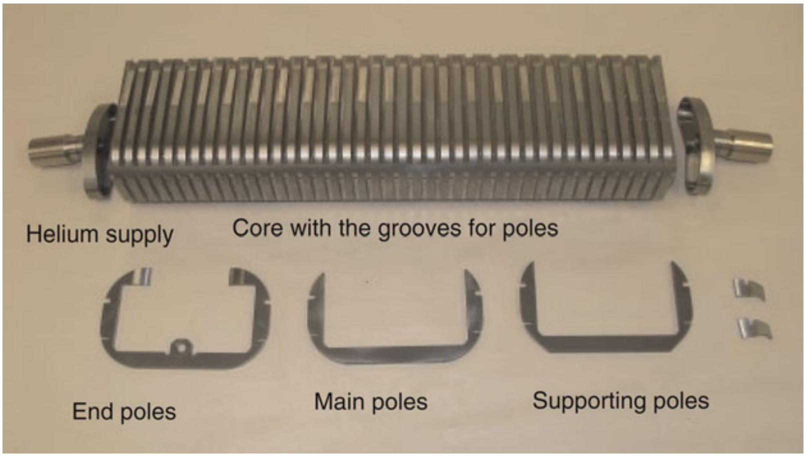

FIGURE 2. Main parts of the core for the magnet structure.

Figure 4. Six stainless steel holders (three on each side) have G-10 inserts in the middle to electrically insulate the top and bottom cores. Insert areas were machined together to achieve 10 μm precision, keeping the pole gap uniform along the whole length to within the same 10 μm tolerance.

In the previous core design, three sets of the poles had so-called extended ‘ears’ for clamping and to define the pole gap. We have replaced them after the first tests with the current supporting poles (figure 2). This change simplified pole manufacturing and winding. Belleville washers were placed under the clamping bolt heads to decrease stresses during the cool-down process in the clamping bolts and G-10 inserts owing to differences in thermal expansion coefficients between stainless and low-carbon steels. In such a design concept, the core could be made of an aluminium alloy for better cooling, or some poles could have different heights to build quasi-periodic undulators (Ivanyushenkov *et al.* 2009). The coil winding of each core half was done in-house on a programmable machine using a 0.7- mm-diameter NbTi wire from ‘Supercon,’ but the winding technology is beyond the scope of this presentation. The initial impregnation was made at Fermilab using CTD-101 epoxy; now an impregnation facility has become operational at the Advanced Photon Source. The prototype core was placed in the LHe-filled vertical cryostat.

FIGURE 3. Assembled core.

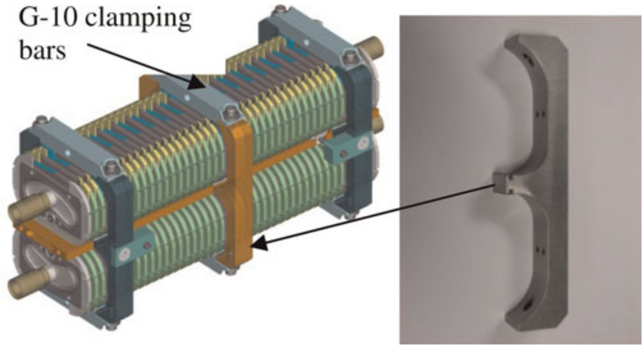

FIGURE 4. Two halves of the magnet structure for the SCU0 and gap-defining holders.

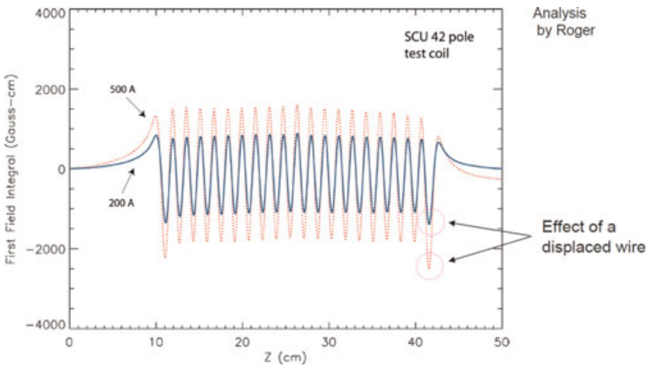

FIGURE 5. First field integrals for the prototype at 200 and 500 A coil current.

Magnetic measurements confirmed the precision of the core manufacturing and winding process. A field measurement is shown in figure 5.

Magnetic measurements showed the quality of the coil winding; without magnetic field corrections the phase error requirements of 8° is met, with a 7.1° phase error at the current needed for 20 keV photons and 3.3° phase error at the current for 25 keV.

3. Conclusion

Three SCU cores have been manufactured for the SCU0 project. Two best cores will be selected for the final assembly. The design of the cryostat is in the final stage, and we plan to install the first planar SCU0 in the storage ring in 2012.

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REFERENCE

IVANYUSHENKOV, Y., TRAKHTENBERG, E.M. & SASAKI, S. 2009 A concept for a quasi-periodic planar superconducting undulator. In *Particle Accelerator Conference (PAC09)*, Vancouver, Canada.